metal-organic papers

Sodium monensin dihydrate

Filipe A. Almeida Paz,[a]
Paul J. Gates,[a]* Stan Fowler,[a]
Andrew Gallimore,[a] Barbara
Harvey,[a] Norberto P. Lopes,[b]
Christian B. W. Stark,[c] James
Staunton,[a] Jacek Klinowski[a] and
Jonathan B. Spencer[a]

[a]Department of Chemistry, University of
Cambridge, Lensfield Road, Cambridge
CB2 1EW, England, [b]Universidade de São
Paulo, Faculdade de Ciências Farmacêuticas
de Ribeirão Preto, Via do Café S/N,
CEP 14.040-903, Ribeirão Preto-SP, Brazil, and
[c]Institut für Chemie, Organishe Chemie, Freie
Universität Berlin, Takustraße 3, 14195 Berlin,
Germany

Correspondence e-mail:
pjg1002@hermes.cam.ac.uk

Key indicators

The crystal structure of the title compound, $[Na(C_{36}H_{61}O_{11})]\cdot 2H_2O$, was first reported by Duax *et al.* [*J. Am. Chem. Soc.* (1980), **102**, 6725–6729]. We report here the crystal structure of a new polymorph, determined at the low temperature of 180 (2) K, in the same orthorhombic non-centrosymmetric space group $P2_12_12_1$. The structure contains one crystallographically unique sodium monensin complex, showing a highly distorted octahedral coordination environment for Na^+, forming undulating layers in the *ac* plane. H atoms from the pendant hydroxyl groups involved in head-to-tail hydrogen bonding with the carboxylate group and from the crystallization water molecules occupying the interlayer spaces have been successfully located in difference Fourier maps.

Comment

Monensin is a commercially important polyether ionophoric antibiotic, first isolated by Agtarap *et al.* (1967). Ionophoric antibiotics readily complex alkali and alkaline earth metal ions *via* their tetrahydrofuranyl O atoms to create shell-like complexes. These complexes act *in vivo* as membrane transports to create a pH gradient that leads to cell death. In addition to antibiotic activity, monensin is also widely used in livestock as a growth promoter and specifically as a coccidiostat in poultry. A search in the Cambridge Structural Database (Version 5.24; Allen, 2002), reveals that the first crystal structures of sodium monensin complexes (an anhydrous form and a dihydrate) were reported by Duax *et al.* (1980). Further structural studies on monensin determined the stereochemistry of the 18 chiral centres (Robinson & Ajaz, 1987) and the NMR solution state conformation (Martinek *et al.*, 2000).
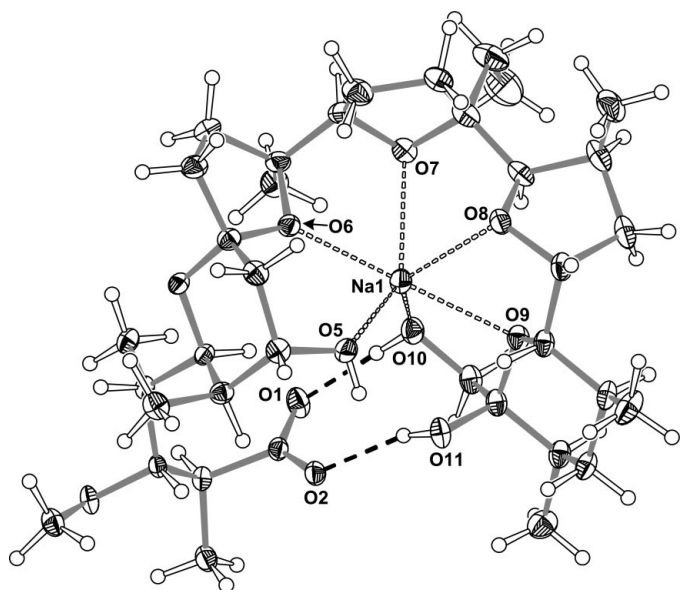

(I)

Our investigations into the structure of monensin isomers require an accurate structure of authenthic monensin for the
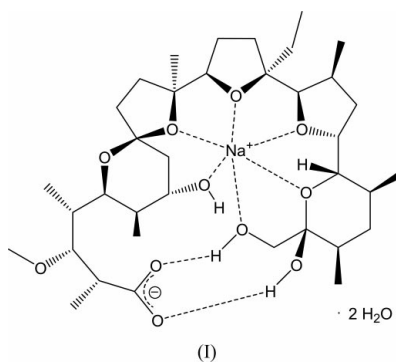
Figure 1
Perspective view of the sodium monensin complex, with all non-H atoms represented as displacement ellipsoids drawn at the 30% probability level, and H atoms shown as small spheres with arbitrary radius. The two crystallization water molecules have been omitted for clarity. Head-to-tail hydrogen bonds between the pendant hydroxyl groups and the carboxylate group are represented as black-filled dashed bonds (for hydrogen-bonding details, see Table 2).
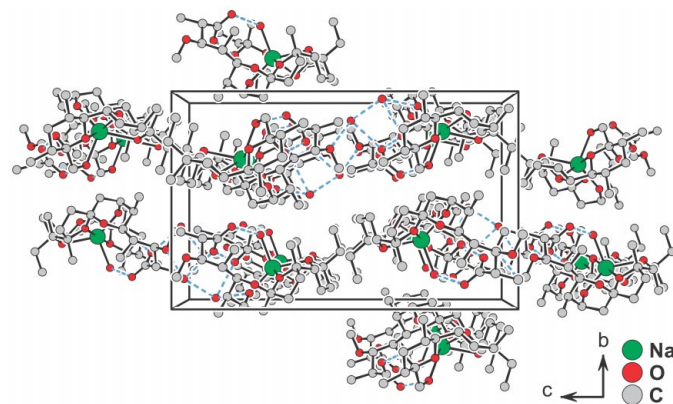

Figure 2
Perspective view along the a axis of (I). The sodium monensin complexes form undulating layers in the ac plane which alternate in the b axis direction in an $ABAB \ldots$ fashion, and are intercalated by the crystallization water molecules which establish hydrogen-bonding bridges between neighbouring complexes within the same layer. Hydrogen bonds are represented as blue-filled dashed lines (for hydrogen-bonding details, see Table 2). H atoms have been omitted for clarity.

facile comparison and elucidation of the stereochemistry of the chiral centres, and the participation of the pendant hydroxyl groups in metal coordination. As part of our research, we came upon a different polymorph for sodium monensin dihydrate, (I), which we report here.

Just like the first sodium monensin dihydrate structure reported by Duax *et al.* (1980), (I) also crystallizes in the non-centrosymmetric orthorhombic space group $P2_12_12_1$, with one whole complex and two water molecules in the asymmetric unit (Fig. 1). Also here, the Na$^+$ centre is coordinated to six O atoms in a geometry which is best described as a highly distorted octahedron (Fig. 1 and Table 1). The Na—O bonds, ranging between 2.336 (4) and 2.520 (3) Å (Table 1), are in very good agreement with the values found by Duax and co-workers [2.336 (7)–2.543 (7) Å]. Intramolecular head-to-tail hydrogen bonding between the pendant hydroxyl groups and the carboxylate group [O10···O1 = 2.643 (4) Å and O11···O2 = 2.665 (4) Å], leads to the formation of a shell-like complex which completely traps the metal centre within the monensin ligand (Fig. 1). Exactly the same was observed in the determination of the earlier polymorph, with calculated $D\cdots A$ distances of 2.51 and 2.64 Å (Duax *et al.*, 1980). Individual sodium complexes close pack in the ac plane, leading to the formation of undulated layers which alternate in an $ABAB \ldots$ fashion in the b axis direction (two layers per axis repeat) (Fig. 2). The crystallization water molecules occupy interlayer spaces and are involved in O—H···O and O—H···O$^-$ interactions which link together neighbouring sodium complexes within the same layer (Fig. 2 and Table 2).

Experimental

Monensin sodium salt was purchased from Aldrich (95% purity) and used without further purification. Crystals suitable for X-ray diffraction analysis were obtained by recrystallization from distilled water.

Crystal data

[Na(C$_{36}$H$_{61}$O$_{11}$)]·2H$_2$O	Mo $K\alpha$ radiation
$M_r = 728.87$	Cell parameters from 73775
Orthorhombic, $P2_12_12_1$	reflections
$a = 12.4768$ (4) Å	$\theta = 1.0$–27.5°
$b = 14.1024$ (4) Å	$\mu = 0.10$ mm^{-1}
$c = 22.1653$ (7) Å	$T = 180$ (2) K
$V = 3900.0$ (2) Å^3	Block, colourless
$Z = 4$	$0.46 \times 0.12 \times 0.07$ mm
$D_x = 1.241$ Mg m^{-3}	

Data collection

Nonius KappaCCD diffractometer	4132 reflections with $I > 2\sigma(I)$
Thin-slice ω and φ scans	$R_{\text{int}} = 0.048$
Absorption correction: multi-scan	$\theta_{\text{max}} = 27.5°$
($SORTAV$; Blessing, 1995)	$h = -16 \rightarrow 16$
$T_{\text{min}} = 0.937$, $T_{\text{max}} = 0.984$	$k = -12 \rightarrow 18$
14637 measured reflections	$l = -28 \rightarrow 28$
4873 independent reflections	

Refinement

Refinement on F^2	$w = 1/[\sigma^2(F_o^2) + (0.0807P)^2$
$R[F^2 > 2\sigma(F^2)] = 0.062$	$+ 2.259P]$
$wR(F^2) = 0.168$	where $P = (F_o^2 + 2F_c^2)/3$
$S = 1.12$	$(\Delta/\sigma)_{\text{max}} < 0.001$
4873 reflections	$\Delta\rho_{\text{max}} = 0.69$ e Å^{-3}
472 parameters	$\Delta\rho_{\text{min}} = -0.56$ e Å^{-3}
H atoms treated by a mixture of	
independent and constrained	
refinement	

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Table 1
Selected geometric parameters (Å, °).

Na1—O5	2.336 (4)	Na1—O8	2.463 (3)
Na1—O6	2.365 (3)	Na1—O7	2.520 (3)
Na1—O10	2.373 (3)	O1—C1	1.242 (5)
Na1—O9	2.459 (3)	O2—C1	1.263 (5)
O5—Na1—O6	75.79 (11)	O10—Na1—O8	122.75 (12)
O5—Na1—O10	117.65 (13)	O9—Na1—O8	64.82 (10)
O6—Na1—O10	112.69 (12)	O5—Na1—O7	136.28 (13)
O5—Na1—O9	103.59 (12)	O6—Na1—O7	68.42 (10)
O6—Na1—O9	178.44 (12)	O10—Na1—O7	99.19 (12)
O10—Na1—O9	68.87 (10)	O9—Na1—O7	111.51 (12)
O5—Na1—O8	104.57 (12)	O8—Na1—O7	69.84 (10)
O6—Na1—O8	113.87 (11)		

Table 2
Hydrogen-bonding geometry (Å, °).

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
O5—H5$\cdots$O13	0.84 (2)	2.04 (3)	2.810 (7)	152 (5)
O10—H10$\cdots$O1	0.84 (2)	1.81 (2)	2.643 (4)	170 (8)
O11—H11$\cdots$O2	0.84	1.88	2.665 (4)	156
O12—H12$E\cdots$O2	0.90 (2)	1.90 (2)	2.791 (4)	174 (5)
O12—H12$D\cdots$O3^{i}	0.91 (2)	2.05 (3)	2.907 (4)	157 (5)
O13—H13$B\cdots$O11	0.986 (10)	2.04 (5)	2.882 (10)	142 (6)
O13—H13$A\cdots$O12	0.988 (10)	1.96 (4)	2.769 (8)	137 (5)

Symmetry code: (i) $\frac{1}{2} + x, \frac{3}{2} - y, 1 - z$.

All H atoms bonded to carbon were placed in calculated positions (C—H = 0.98–1.00 Å) and allowed to ride during subsequent refinement with $U_{iso}(H) = xU_{eq}(C)$ (with x = 1.2 for —CH and —CH$_2$—, and x = 1.5 for methyl groups). H atoms of the hydroxyl groups and of the crystallization water molecules were successfully located in difference Fourier maps. O—H and H$\cdots$H distances were

restrained in order to ensure a chemically reasonable geometry for the hydroxyl groups and also to the water molecules. A total of 3597 estimated Friedel pairs were merged before refinement and not used as independent data. The Flack (1983) parameter was found to be meaningless and was omitted.

Data collection: *COLLECT* (Nonius, 1998); cell refinement: *HKL SCALEPACK* (Otwinowski & Minor, 1997); data reduction: *HKL DENZO* (Otwinowski & Minor, 1997) and *SCALEPACK*; program(s) used to solve structure: *SIR*92 (Altomare *et al.*, 1994); program(s) used to refine structure: *SHELXTL* (Bruker, 2001); molecular graphics: *SHELXTL*; software used to prepare material for publication: *SHELXTL*.

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